SYNOPSIS

This thesis is concerned with the problems of stick-slip vibrations and also of vibration isolation by viscoelastic isolators. The importance of these problems has been brought to light by recent research particularly in the design of precision machine tools.

The author presents a detailed analysis and develops the mechanics of the stick-slip vibration through theoretical and experimental investigations. Stick-slip vibration is executed by an elastic system driven under boundary friction at a velocity lower than a particular critical value for the system. Thus, it is shown that the critical velocity v_c of a system comprising a sliding weight W coupled by a drive of stiffness k and damping ratios of the system ζ_1 and ζ_2 is given by

$$\frac{v_c \cdot \omega_n}{g \cdot \nabla\mu} = \frac{1 + N/W}{\omega_n/\delta + A_c}$$

where : $\omega_n = \sqrt{kg/W}$; $\nabla\mu$ = the difference between the static and kinetic coefficients of friction;

N = normal pressure between the sliding surfaces;
δ is a parameter representing the rate of increase of kinetic friction to its static value during the period of stick; and A_c is a dimensionless parameter given approximately by

$$2(\zeta_1 + \zeta_2) \tan^{-1}\left[\frac{A_c + 4\zeta_1 + 2\zeta_2}{A_c(\zeta_1+\zeta_2) - 1}\right]$$
$$= \log\left[A_c^2 + 2(3\zeta_1 + \zeta_2) A_c + 12\zeta_1^2 + 2\zeta_2^2 + 10\zeta_1\zeta_2 + 1\right]$$

In the case of a system driven with a fluctuating velocity, it has been shown that in general the critical velocity is not greatly affected. However, when the frequency of fluctuations resonates with the natural frequency of the system, the critical velocity may be considerably increased. Again, in the case of an elastic system, where the sliding mass is subjected to forced vibration, it is shown that the critical velocity may be considerably increased, if the frequency of applied force resonates with the natural frequency of the system. However, it is found that at high frequency ratios the stick-slip effect may be completely eliminated.

The critical velocity under a steady drive has been studied on a mechanical model designed for rectilineal motion on a milling machine. This arrangement is also simulated on an electric analogue computer. Good correlation has been observed between the theoretical values, the experimental values on the mechanical model and those obtained from the analogué computer. The other cases for the critical velocity under fluctuating drive and forced vibration also were simulated on the electric analogue computer where the control and variation of different parameters could be effected in the desired manner with a relative case. The results are then presented graphically in terms of non-dimensional parameters.

The problem of errors and sensitivity of slow shifting resulting from the stick-slip process is also investigated. Experimental observations made on the mechanical model corroborate well with the theoretical analysis. The results are then discussed and some practical methods for the elimination of stick-slip and improvement of sensitivity in machine tools have been discussed.

Finally, the problem of viscoelastic vibration isolators in machine tools and other machinery is taken up. This is preceeded by a brief review of the principles of classical vibration isolators for single degree of freedom with coupled modes and two degrees of freedom systems. The expression for the force transmissibility of viscoelastic isolators is derived by taking account of the creep and relaxation properties of such isolators. It is found that at higher frequency ratios the transmissibility is lower than that obtained in the case of a classical isolator scheme. The results are presented in graphical form in terms of non-dimensional parameters.

On account of the important role played by damping in controlling vibration, analysis of various types of damping of vibration and that of damping and fatigue under resonance vibration is presented in an appendix.